 Report No. 953

# FINAL REPORT ON A BROADBAND LOGARITHMICALLY PERIODIC ANTENNA

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# FINAL ENGINEERING REPORT

# ON

# A BROADBAND LOGARITHMICALLY PERIODIC ANTENNA

## 1. INTRODUCTION

### 1.1 Statement of Problem

The work reported is for the design and development of a unidirectional broadband logarithmically periodic antenna. The frequency range of the antenna should be 30-600 mc and designed for indoor and outdoor use. When used indoors, it must fit within the confines of a room 9 feet x 9 feet x 7 feet. Furthermore, the design of the antenna must be such that it can be disassembled into parts which will fit in two boxes with outside dimensions of 20 inches x 20 inches x 12 inches.

The electrical characteristics should provide an impedance match with a vswr as low as possible over the entire range of the antenna. A vswr of 2:1 will be set as the design objective. Radiation characteristics which are desired are high gain and a high front-to-back ratio. Freedom of rotation in the azimuthal plane should be provided and manual change of polarization is also necessary. Two feed cables must be provided with the antenna, a 150-ohm balanced line and a 50-ohm coaxial line.

### 1.2 Brief Statement of Final Data

Due to the limitation imposed on the overall size of the antenna, the lower frequency limit of 30 mc was not achieved. The minimum frequency which was obtained is 55 mc. Final vswr measurements indicated a maximum mismatch of 2.5:1 in the range from 55 to 600 mc, and the gain of the antenna varied from 4.2 db to 8.2 db over a dipole throughout the range of the antenna. The average front-to-back ratio was approximately 14 db. The variations in gain and front-to-back ratio were mainly due to the capacity end-loading of the longest two elements on the antenna.

## 2. STATEMENT OF ANTENNA CONFIGURATION AS DETERMINED BY SCALE-MODEL WORK

In the early stages of the design, several scale models were constructed and tested. Several combinations of design parameters were investigated in an attempt to obtain the desired results. The results of this preliminary investigation dictated the final design parameters which are $\alpha = 60°$, $\tau = .6$ and $\psi = 35°$. Figure 1 shows a sketch of a typical unidirectional logarithmically periodic antenna with associated design parameters. For further references on this type of antenna, the reader is referred to referenced articles.[1, 2]

### 2.1 Loading

This type of logarithmically periodic antenna has a lower frequency limit which is defined when the longest transverse wire is approximately a half wavelength long. This condition affected one of the specifications, that of containing the assembled antenna in a room 9 feet x 9 feet x 7 feet. With a minimum dimension of 7 feet, this meant that the longest element could be only 7 feet long, and therefore, the antenna would have a lower frequency limit of approximately 70 mc. Therefore, it was necessary to load the antenna in some way to reduce the lower frequency limit for a given back-element length, viz. 7 feet. Two schemes of artifically loading the antennna were tried. One method of loading involved making the elements of a zig-zag construction. Figure 2 is a sketch of one half of an antenna structure showing the zig-zag elements. This type of loading reduced the lower frequency limit approximately 30 per cent, but after examining the mechanical problems involved, it was decided that this type of construction would not be feasible for use on such a large structure. The second method, which was ultimately used, incorporated capacity end-loading the elements as shown in figure 3. Although this did not give the reduction that was experienced with the other form of loading, it proved to be feasible for construction. An 18 per cent reduction in size was now observed, but this reduction was not obtained without a slight loss of performance which will be discussed later.

### 2.2 Impedance Measurements

Impedance measurements were also conducted on the scale models. As in previous structures of this nature, it was observed that the characteristic impedance was approximately

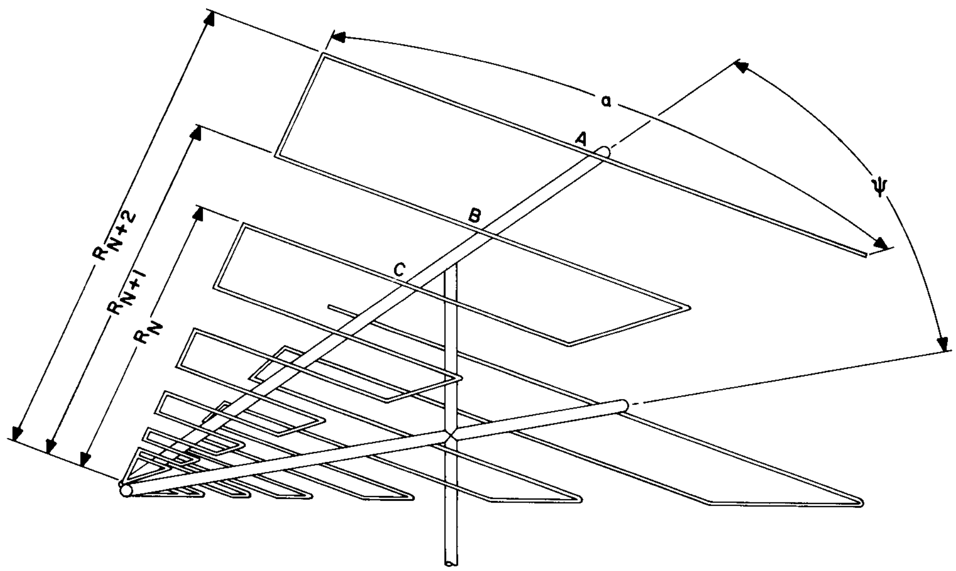


Figure 1. Sketch Showing Design Parameters of Log Periodic Antenna

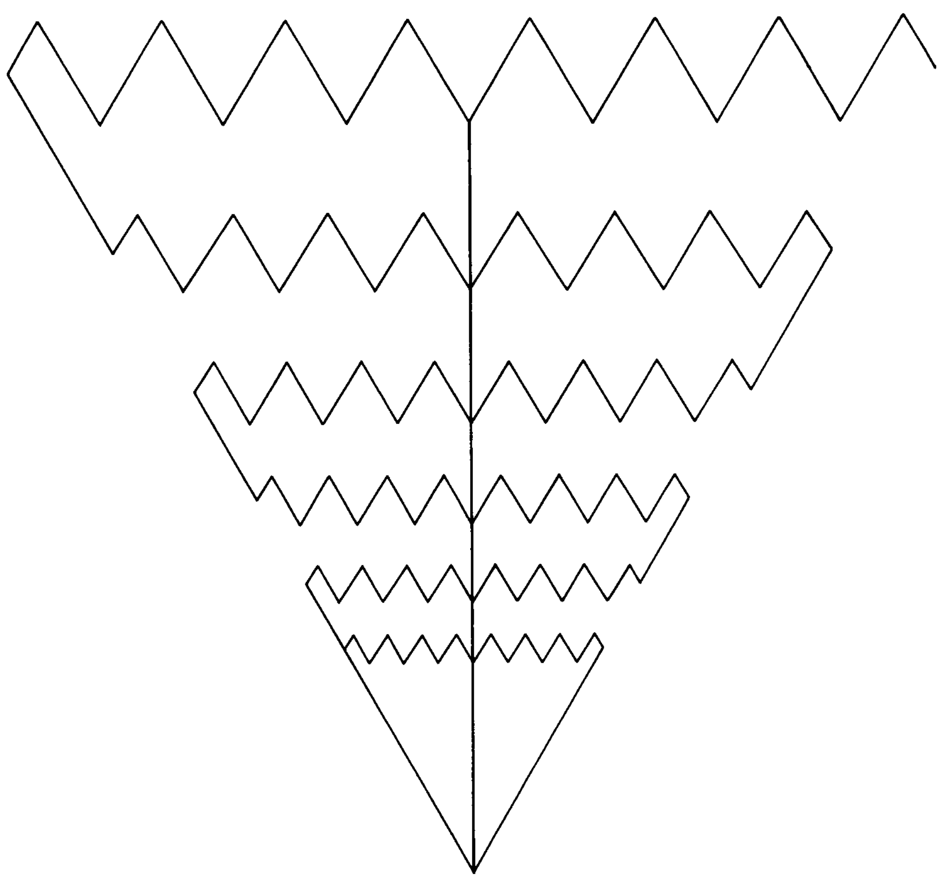

Figure 2. One Half of Antenna Structure Showing Use of Zig-Zag Elements



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150 ohms. Since the two types of feed cables to be used were a 150-ohm balanced line and a 50-ohm coaxial line, some form of an impedance-matching device was necessary for use with the 50-ohm coaxial line.

The nature of these antennas is such that the two half-structures are fed against each other. In the case of the coaxial feed, the center conductor, which is contained in the lower boom, is brought out at the apex end of the antenna and is connected to the upper boom. This causes the two halves of the antenna to have equal and properly phased currents.

When the balanced line is used, it is suspended between the two halves of the antenna as shown in figure 4. The connection of this line is also made at the apex end of the antenna by connecting one side of the line to the upper half of the antenna and the other side of the line to the lower half. This results in a current distribution which is identical to that of the coaxial feed.

2.3 Gain Measurements

An approximate method of determining the gain of an antenna is by use of the formula $G = \frac{41,250}{\phi_1 \phi_2}$ ($\phi_1$ and $\phi_2$ are the principal-plane half-power beamwidths). This method has been used in calculating the gain figures of this particular antenna, but experimental gain measurements were also conducted to justify the use of the formula. The measurement procedure employed was that of obtaining gain by the comparison method. A calibrated horn was used as the reference antenna in this comparison method. After performing the measurements, the actual gain of the antenna corresponded within .2 of a db to the gain obtained by computing it from the formula using measured patterns.

3. FULL-SCALE DESIGN

The design of the full-scale antenna was such that it could be disassembled into small parts which could be packed in two boxes 20 inches x 20 inches x 12 inches. Aluminum was used for all components of the antenna with the exception of the tapered coaxial line. In keeping with the size specification of the shipping boxes, it was necessary that the construction of the antenna and supporting structure be such that it would fit into these boxes.

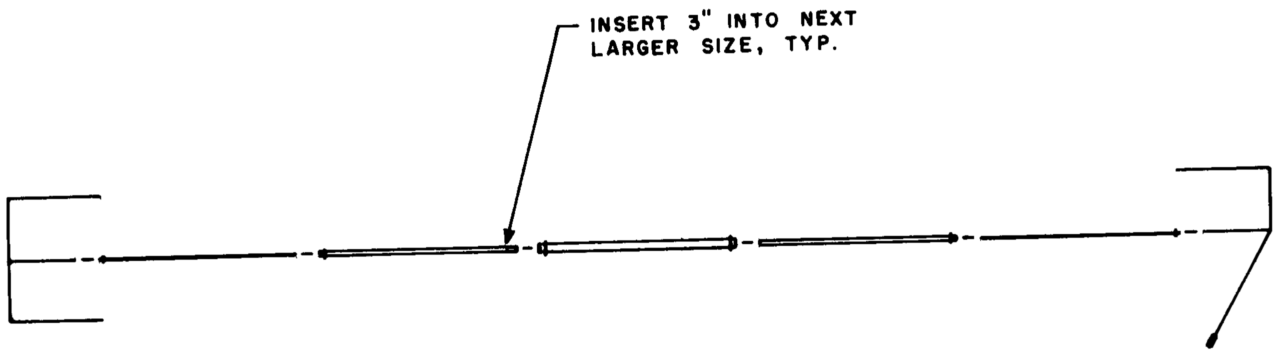



Figure 3. Typical Element Construction also Showing Capacity End Loading

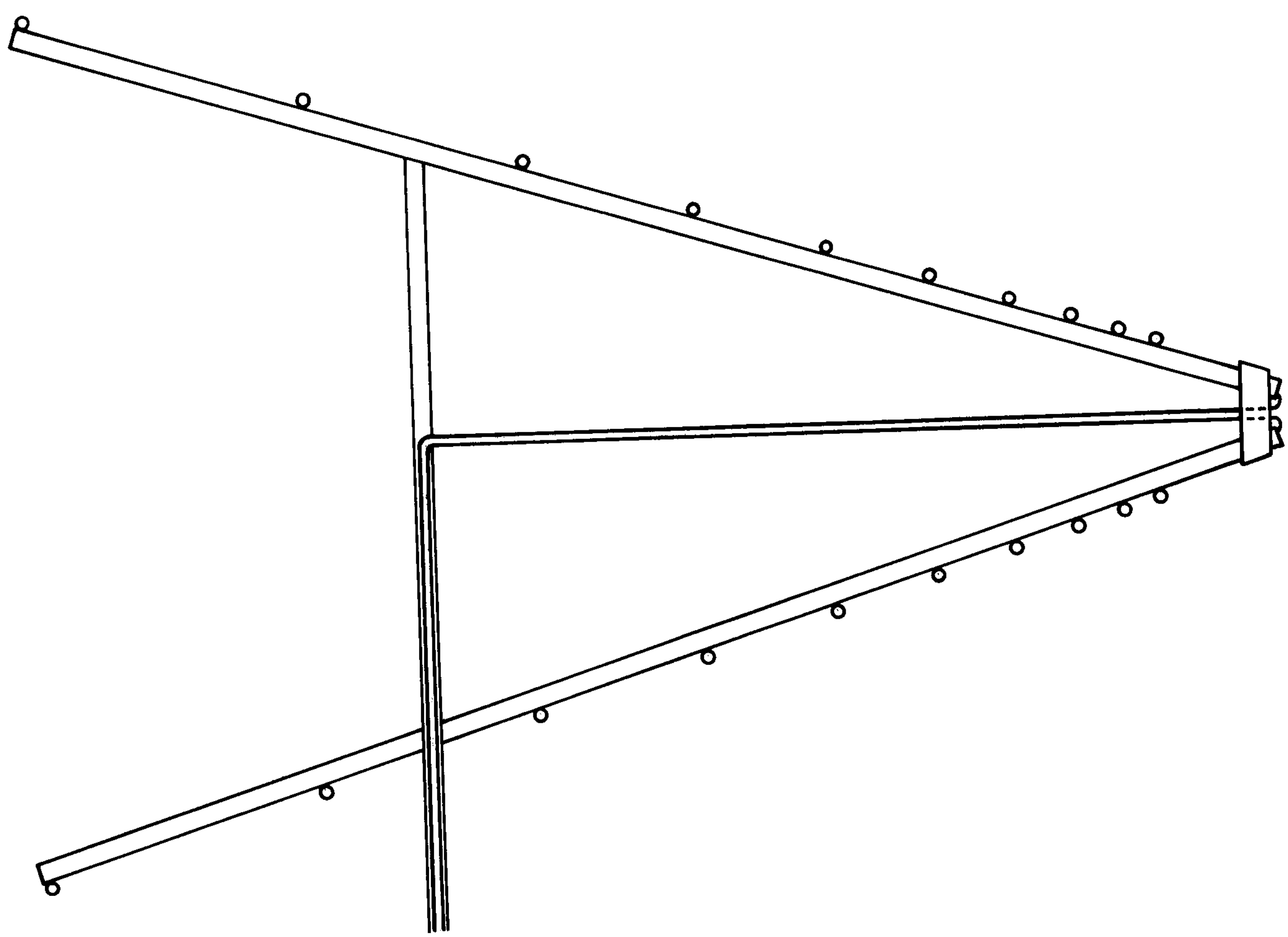


Figure 4. Sketch of Antenna Showing Mounting of Balanced Line

Telescoping-type elements were designed with little clamps bonded to one end of each section. A scribed line was placed around the circumference of each section at the proper distance from the end to indicate how far it should be inserted into the next larger-size tube. Figure 3 shows a typical element of the antenna. The construction of the booms which support the elements and also the vertical supporting mast were made similar to the elements. Where necessary, a mark was placed for proper insertion depth. Clamps were also bonded to these sections for ease of construction.

Manual change of polarization is obtained by means of a rotating joint which is located midway between the upper and lower halves of the antenna. This joint is eccentric to the vertical axis of rotation and thus provides ease of polarization change. Figure 5 shows how this polarization change is obtained.

In order to design the tapered line properly, it was decided to obtain the impedance of the antenna and then design the tapered line to conform exactly to the impedance level of the antenna. Figure 6 shows a Smith Chart plot of the antenna impedance. The characteristic impedance was 140 ohms, and based upon this figure, the impedance tapered line was designed to match 50 ohms to 140 ohms. The design of the taper was obtained from an article by Klopfenstein[3] in which the Dolf-Tschebycheff distribution is used. The changing characteristic impedance of the tapered line along its length is determined so that the input reflection coefficient follows a Tschebycheff response in the passband of the taper. In this design the length of the tapered line is one of the important factors which determines the maximum reflection coefficient. Unfortunately, the available length, i.e., the length of the boom, in this antenna was not adequate to maintain the reflection coefficient at a very low level. As a result, the vswr of the tapered line, terminated in a matched load, was 1.26:1. This then, in conjunction with the impedance spread of the antenna, caused the final vswr to be greater than 2:1 over the frequency range of the antenna. The tapered line was foamed into place by using a lockfoam compound of 6 pounds per cubic foot. This foaming keeps the center conductor rigidly placed and, furthermore, makes the assembly of the boom very simple and easy. Figures 7, 8 and 9 show blown-up assembly views of various portions of the antenna

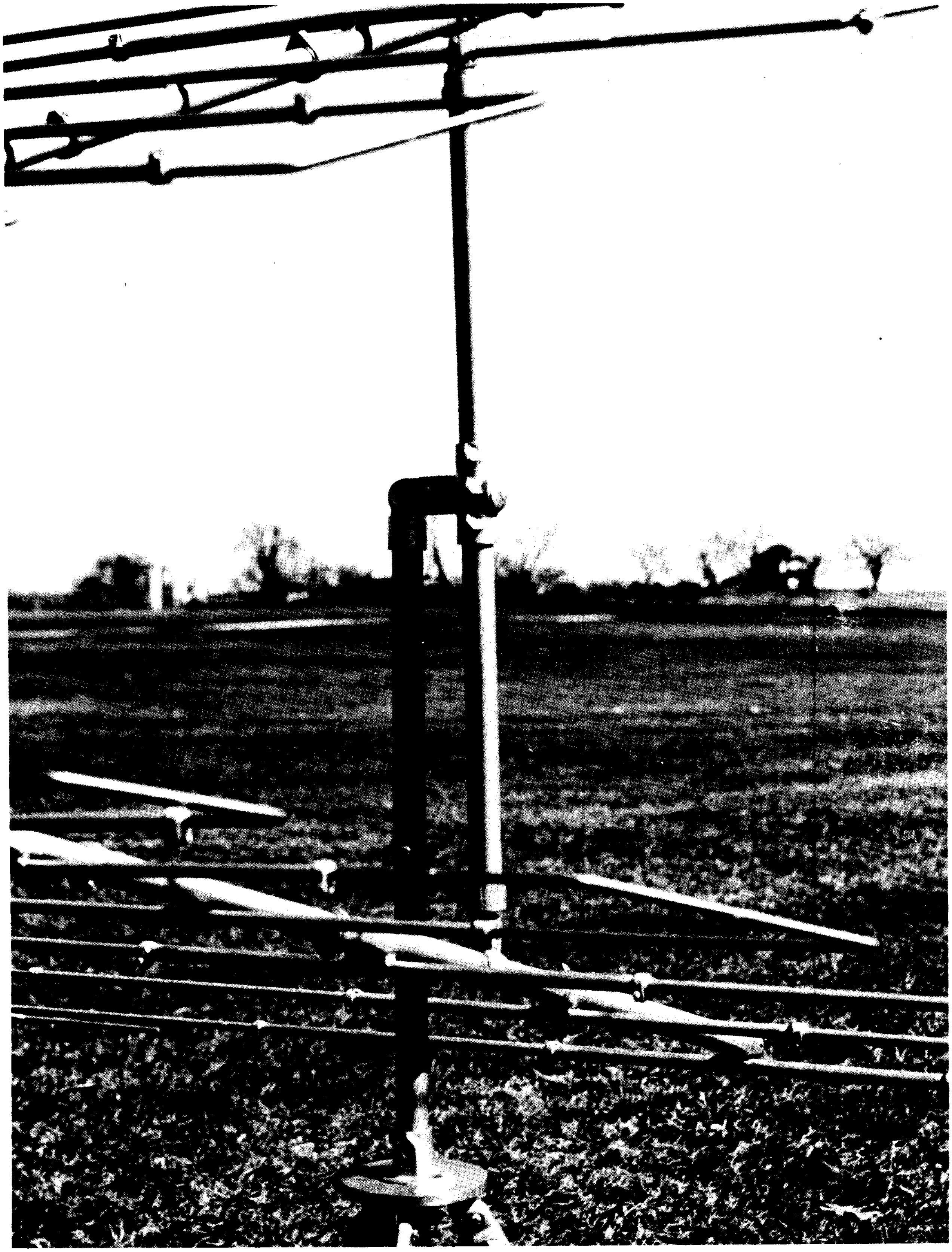


Figure 5. Photograph Showing How Polarization Change is Obtained

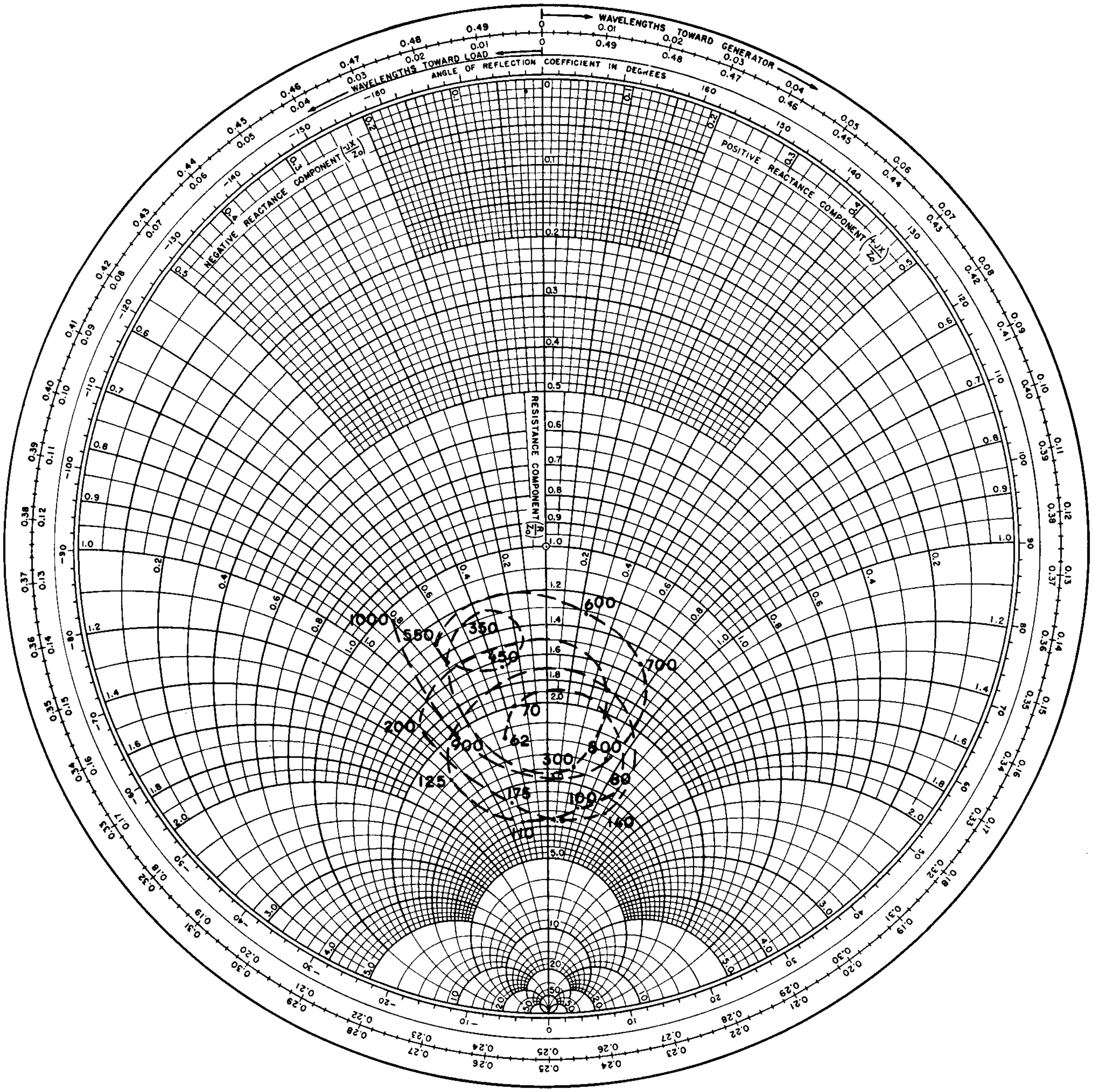
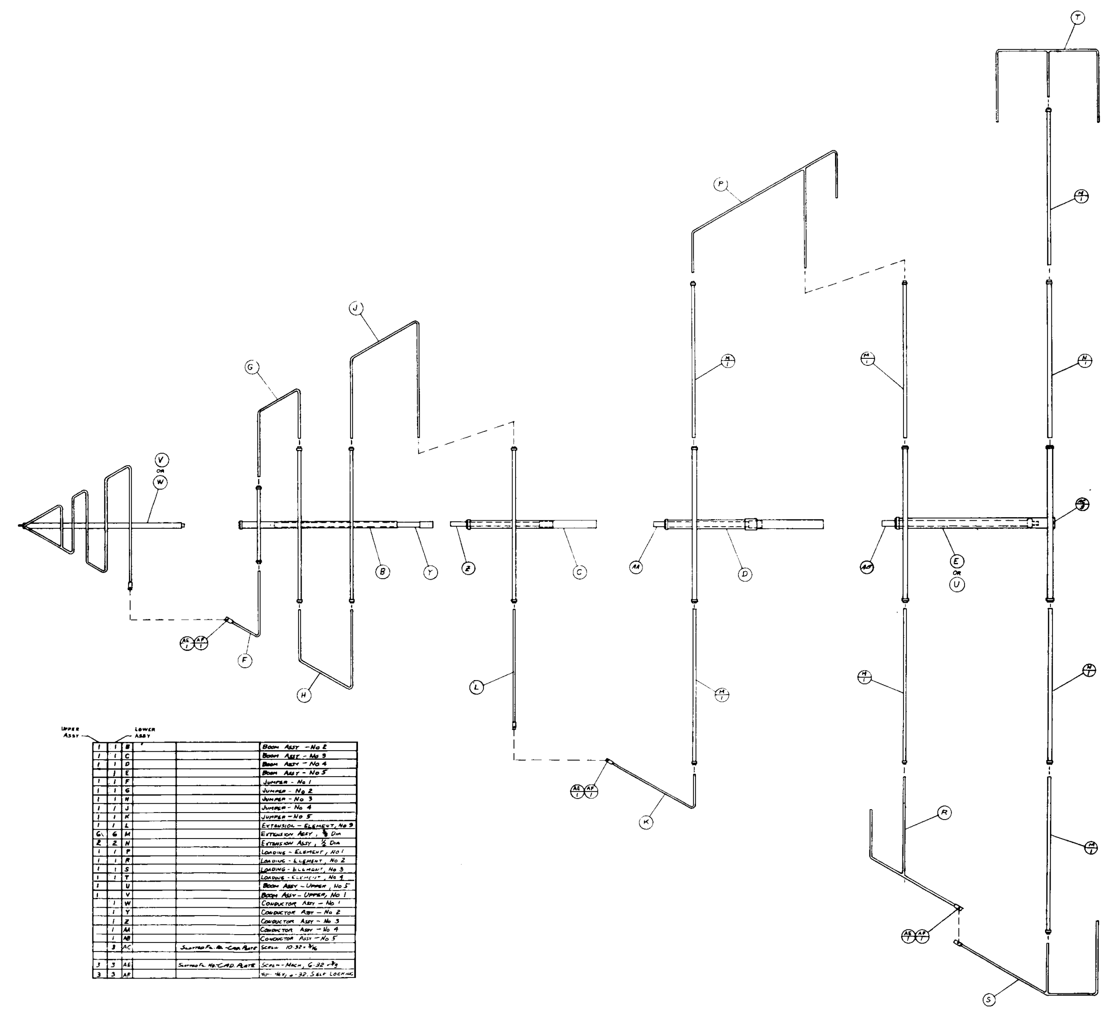



Figure 6. Impedance Plot of Antenna Normalized to 50 Ohms




| Upper Assy | Lower Assy | | | | |
|---|---|---|---|---|---|
| 1 | 1 | B | | | Boom Assy - No 2 |
| 1 | 1 | C | | | Boom Assy - No 3 |
| 1 | 1 | D | | | Boom Assy - No 4 |
| | 1 | E | | | Boom Assy - No 5 |
| 1 | 1 | F | | | Jumper - No 1 |
| 1 | 1 | G | | | Jumper - No 2 |
| 1 | 1 | H | | | Jumper - No 3 |
| 1 | 1 | J | | | Jumper - No 4 |
| 1 | 1 | K | | | Jumper - No 5 |
| 1 | 1 | L | | | Extension - Element, No 3 |
| 6 | 6 | M | | | Extension Assy, 3/8 Dia |
| 2 | 2 | N | | | Extension Assy, 1/2 Dia |
| 1 | 1 | P | | | Loading - Element, No 1 |
| 1 | 1 | R | | | Loading - Element, No 2 |
| 1 | 1 | S | | | Loading - Element, No 3 |
| 1 | 1 | T | | | Loading - Element, No 4 |
| 1 | | U | | | Boom Assy - Upper, No 5 |
| 1 | | V | | | Boom Assy - Upper, No 1 |
| | 1 | W | | | Conductor Assy - No 1 |
| | 1 | Y | | | Conductor Assy - No 2 |
| | 1 | Z | | | Conductor Assy - No 3 |
| | 1 | AA | | | Conductor Assy - No 4 |
| | 1 | AB | | | Conductor Assy - No 5 |
| | 3 | AC | | Slotted Fl. Hd. - Cad. Plate | Screw 10-32 × 3/16 |
| | | | | | |
| 3 | 3 | AE | | Slotted Fl. Hd. Cad. Plate | Screw - Mach, 6-32 × 3/8 |
| 3 | 3 | AF | | | Nut - Hex, 6-32, Self Locking |

Figure 7. Expanded View of One Half of the Antenna Structure Showing Assembly Procedure



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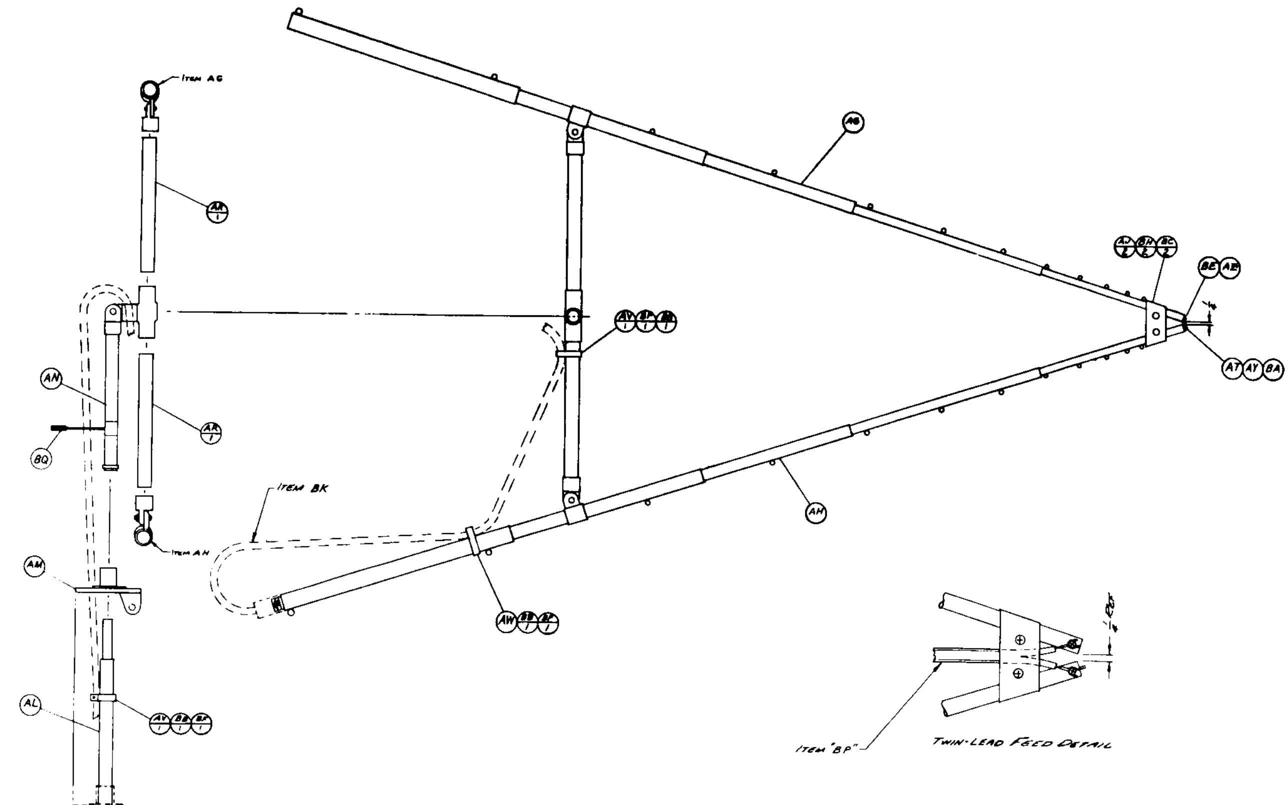
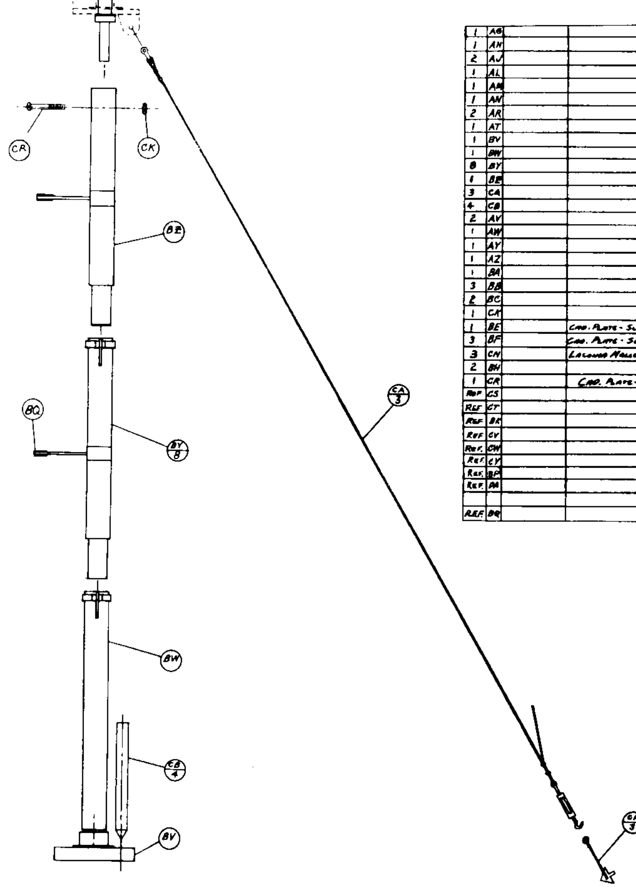
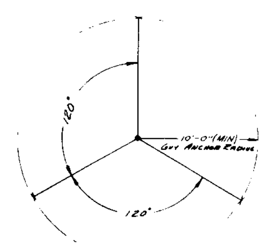



| | | | | |
|---|---|---|---|---|
| 1 | AG | | | BOOM ASSY - UPPER |
| 1 | AH | | | BOOM ASSY - LOWER |
| 2 | AJ | | | INSULATOR - APEX |
| 1 | AL | | | MAST SECTION - BEARING |
| 1 | AM | | | BEARING ASSY |
| 1 | AN | | | MAST ASSY - SECTION 5 |
| 2 | AR | | | SPACER - ANTENNA |
| 1 | AT | | | FEED STRAP |
| 1 | BV | | | PLATE - BOTTOM (ASSY) |
| 1 | BW | | | MAST SECTION - No 1 |
| 8 | BY | | | MAST SECTION - No 2 |
| 1 | BZ | | | MAST SECTION - No 3 |
| 3 | CA | | | GUY ASSY |
| 4 | CB | | | ROD - ANCHOR |
| 2 | AV | | | CLAMP - CABLE, 1.55 ID |
| 1 | AW | | | CLAMP - CABLE, 2.05 |
| 1 | AY | | | WASHER - LOCK, No 4 BRASS |
| 1 | AZ | | | WASHER - LOCK, No 4 S S |
| 1 | BA | | | NUT - HEX, 4-40, BRASS |
| 3 | BB | | | NUT - HEX, 10-32, SELF LOCKING |
| 2 | BC | | | NUT - HEX, 1/4-20, SELF LOCKING |
| 1 | CK | | | NUT - HEX, 3/8-16, SELF LOCKING |
| 1 | BE | | CAD. PLATE - SLOTTED HEAD | SCREW - MACH - 4-40 × 1/2 |
| 3 | BF | | CAD. PLATE - SLOTTED HEAD | SCREW - MACH - 10-32 × 1/2 |
| 3 | CN | | LACQUER MALLEABLE IRON | 4" ARROWHEAD ANCHOR (ALU |
| 2 | BH | | | SCREW MACH - 1/4-20 × 1 1/4 |
| 1 | CR | | CAD. PLATE - SLOTTED HEAD | SCREW - 3/8-16 × 2 1/2 |
| REF | CS | | | 5/32 ALLEN WRENCH |
| REF | CT | | | 3/16 ALLEN WRENCH |
| REF | BK | | | COAXIAL CABLE ASSY. |
| REF | CV | | | FLAT BLADED SCREW DRIVER |
| REF. | CW | | | PHILLIPS SCREW DRIVER |
| REF. | CY | | | 6" ADJUSTABLE WRENCH |
| REF. | BP | | | TWIN-LEAD FEED ASSY. |
| REF. | DA | | | DRIVE ROD - ANCHOR |
| | | | | |
| REF. | BQ | | | STAND-OFF INSULATOR |



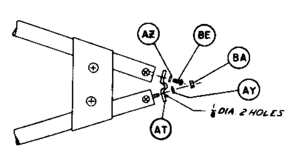
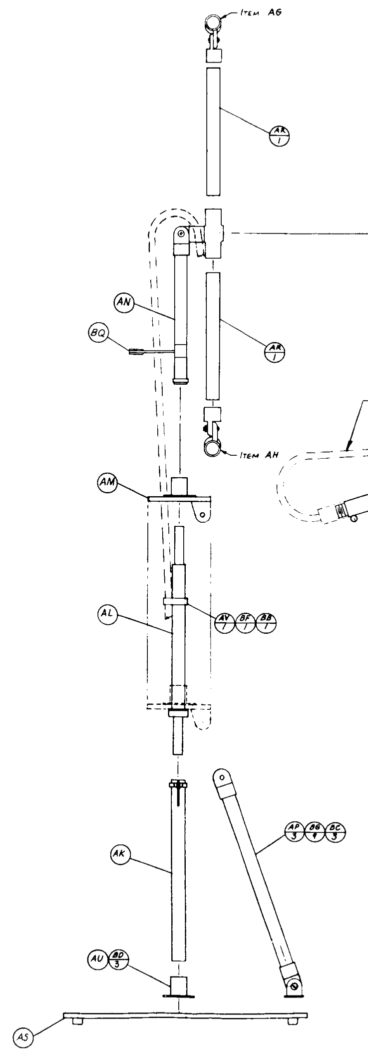
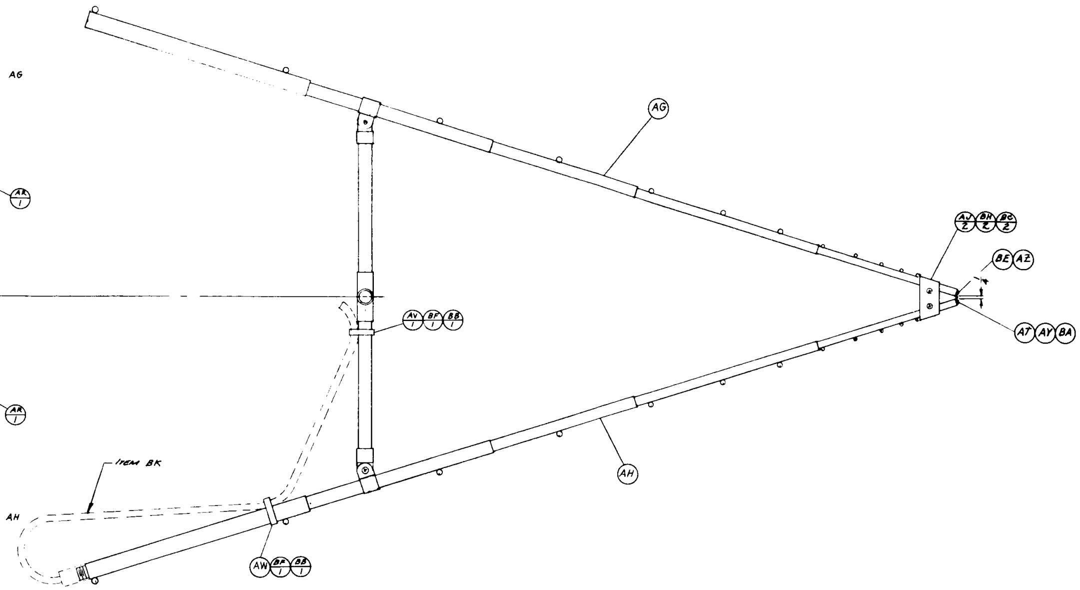





Figure 8. Expanded View of Outdoor Installation Showing Assembly Procedure




| | | | | |
|---|---|---|---|---|
| 1 | AG | | | BOOM ASSY – UPPER |
| 1 | AH | | | BOOM ASSY – LOWER |
| 2 | AJ | | | INSULATOR – APEX |
| 1 | AK | | | MAST SECTION – NO 4 |
| 1 | AL | | | MAST SECTION – BEARING |
| 1 | AM | | | BEARING ASSY |
| 1 | AN | | | MAST ASSY – SECTION 5 |
| 3 | AP | | | TRIPOD LEG ASSY |
| 2 | AR | | | SPACER – ANTENNA |
| 1 | AS | | | COVER – BOX, DUAL PURPOSE |
| 1 | AT | | | FEED STRAP |
| | | | | |
| | | | | |
| 1 | AU | | HOSKING – NO 150 3/4 PIPE | FLANGE – ROUND BASE |
| 2 | AV | | | CLAMP – CABLE, 1.55 |
| 1 | AW | | | CLAMP – CABLE, 2.05 |
| 1 | AY | | | WASHER – LOCK, NO 4, BRASS |
| 1 | AZ | | | WASHER – LOCK, NO 4, SS |
| 1 | BA | | | NUT – HEX, 4-40, BRASS |
| 3 | BB | | | NUT – HEX, 10-32 SELF LOCKING |
| 3 | BC | | | NUT – HEX, 1/4-20 SELF LOCKING |
| 3 | BD | | CAD. PLATE – SLOTTED HEAD | SCREW – MACH, 1/4-20 × 7/8 FLAT HD |
| 1 | BE | | CAD. PLATE – SLOTTED HEAD | SCREW – MACH, 4-40 × 1/2 |
| 3 | BF | | CAD. PLATE – SLOTTED HEAD | SCREW – MACH, 10-32 × 1/2 |
| 9 | BG | | CAD. PLATE – SLOTTED HEAD | SCREW – MACH, 1/4-20 × 1 |
| 2 | BH | | CAD. PLATE – SLOTTED HEAD | SCREW – MACH, 1/4-20 × 1 1/4 |
| REF | BJ | | | 5/32 ALLEN WRENCH |
| REF | BK | | | COAX CABLE ASSY |
| REF | BL | | | FLAT BLADED SCREW DRIVER |
| REF | BM | | | PHILLIPS SCREW DRIVER |
| REF | BN | | | 6" ADJUSTABLE WRENCH |
| REF | BP | | | TWIN LEAD CABLE ASSY |
| REF | BQ | | | STAND-OFF INSULATOR |
| | | | | |

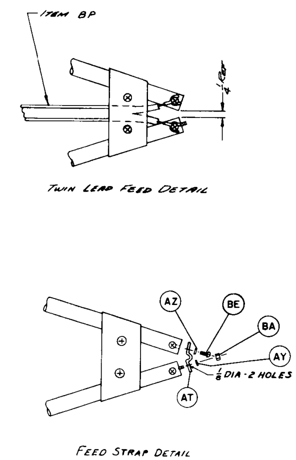



Figure 9. Expanded View of Indoor Installation Showing Assembly Procedure



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and supporting structure which enable the antenna to be assembled by relatively inexperienced personnel in a short period of time. Figures 10 and 11 are photographs of the antenna showing both the indoor and outdoor mounts.

## 4. FULL-SCALE MEASUREMENTS

Figures 12 and 13 show a series of patterns taken over the entire frequency range of the antenna. Figure 12 represents the horizontal-polarization azimuthal-plane patterns, and figure 13 represents the vertical-polarization azimuthal-plane patterns. It is noted that the large beamwidths in the vertical polarization patterns at the lower frequencies are due to the capacity end-loading of the antenna. Figure 14 shows patterns of the antenna taken below the lower cutoff frequency. As can be seen, the cross polarization becomes the dominant polarization as the frequency is decreased. The gain figures as shown in figure 15 are calculated figures as obtained from the principal-plane beamwidths and, as mentioned before, are quite accurate. Figures 12 and 13 also show patterns taken above the upper design limit to show the deterioration of the main beam and also the decrease in front-to-back ratio. Figure 16 shows a plot of vswr versus frequency. This plot also shows vswr measurements beyond the upper design limit and, as can be seen, it remains quite good up to 1000 mc. Also shown is the vswr down to 30 mc, and as can be seen, the cutoff of the antenna is quite sharp at the lower limit.

## 5. CONCLUSIONS

The results which have been presented have shown that all but one of the specifications have been fulfilled. The size limitation imposed, limited the lower frequency limit of the antennna to 55 mc. It is felt that after considering the type of construction used on the antenna, the results were quite gratifying. Although a vswr of 2:1 was set as a design objective, the degradation from 2.5:1 to 2:1 is not serious enough to affect the performance to any appreciable amount. The large number of mechanical connections certainly were an important factor in the impedance variations as were shown on the Smith Chart plot. The impedance spread in conjunction with the short length of boom available for the tapered line caused the vswr to exceed 2:1.

The knowledge gained from this design will certainly be of value in any future work which could possibly be done along these lines.

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2. R. H. DuHamel and F. R. Ore, "Logarithmically Periodic Antenna Designs", 1958 IRE Convention Record, Part I, pp. 139-151.

3. R. W. Klopfenstein, "A Transmission Line Taper of Improved Design", Proc. of IRE, January 1956, pp. 31-35.

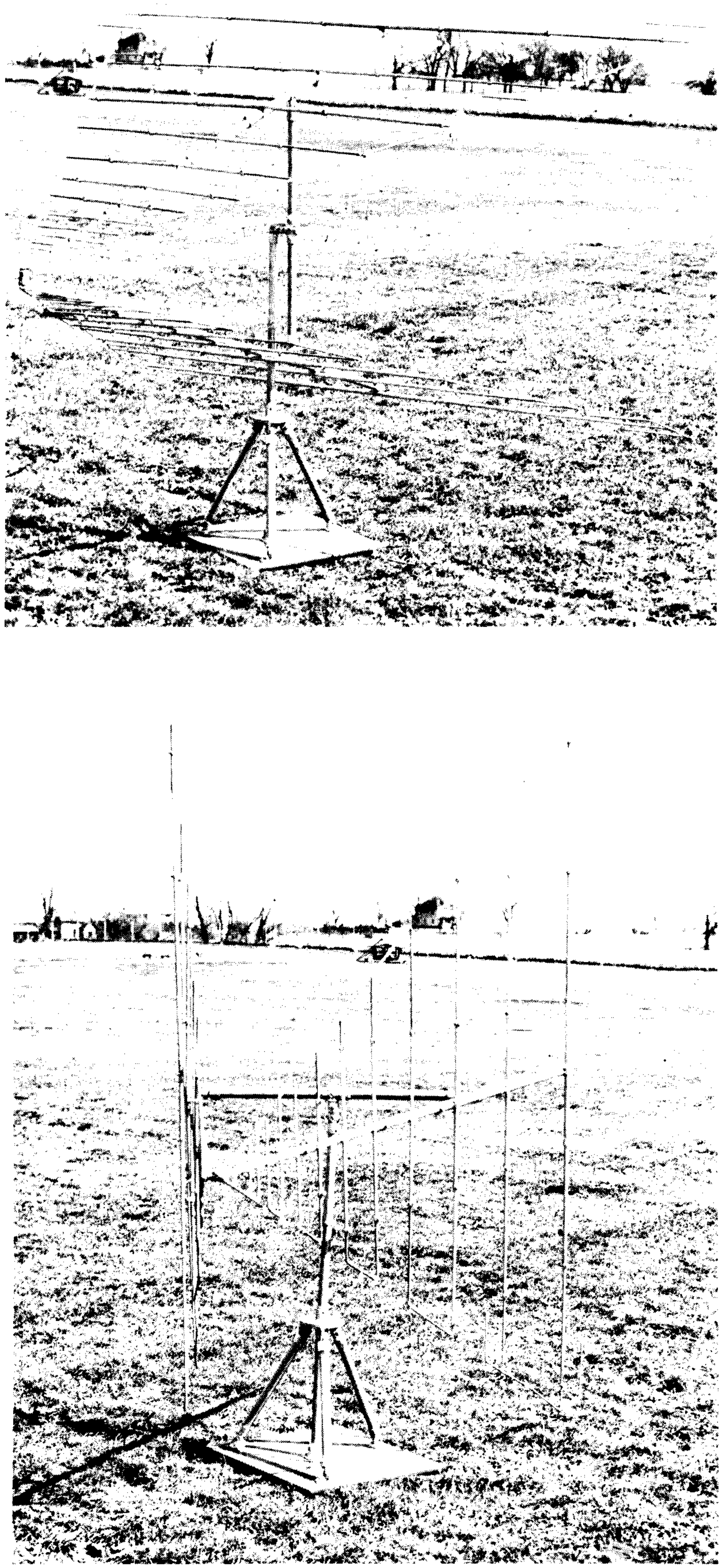

Figure 10. Antenna Mounted for Indoor Use

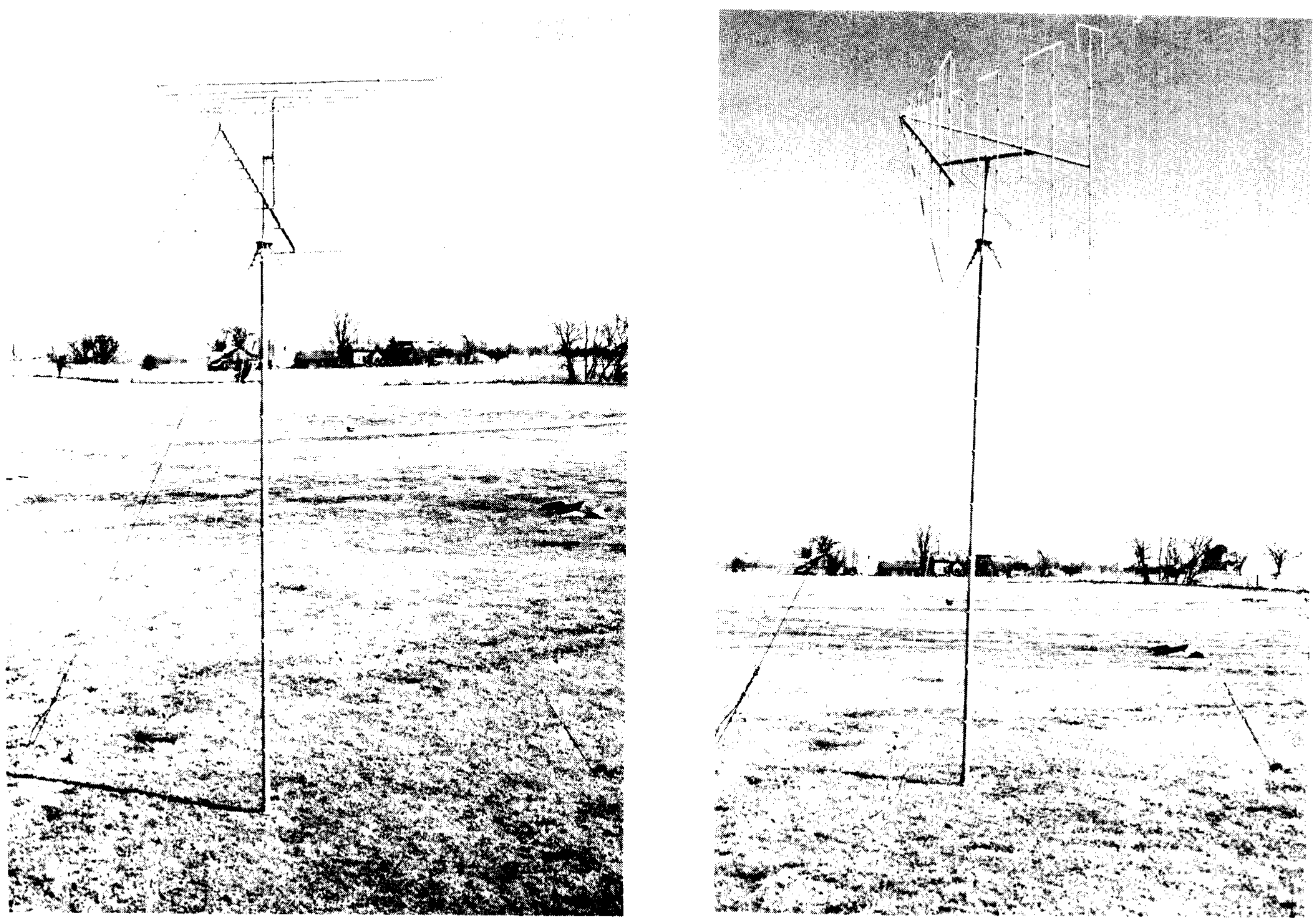

Figure 11. Antenna Mounted for Outdoor Use

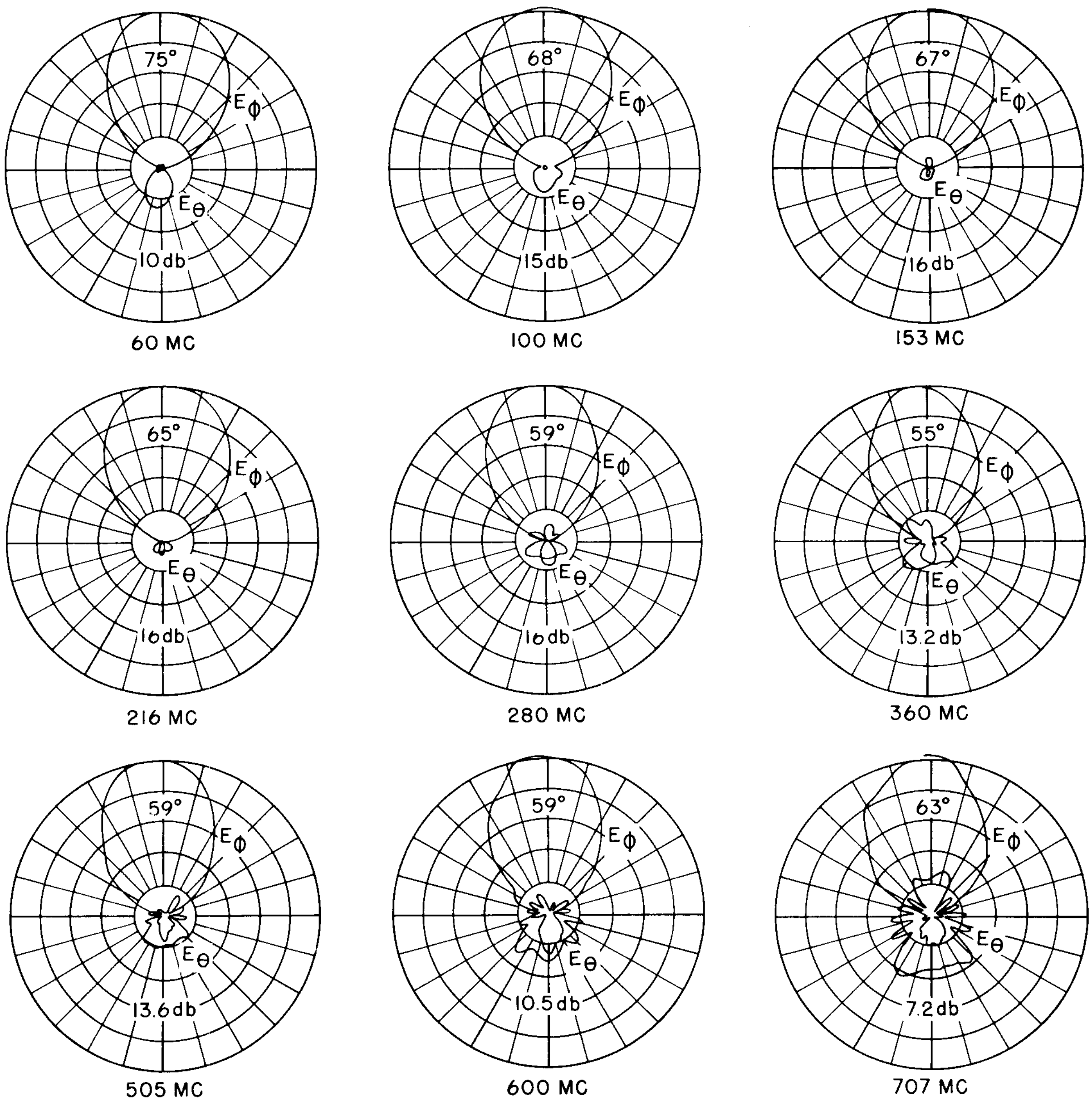


Figure 12. Horizontal Polarization Relative Voltage Patterns Taken in Azimuthal Plane

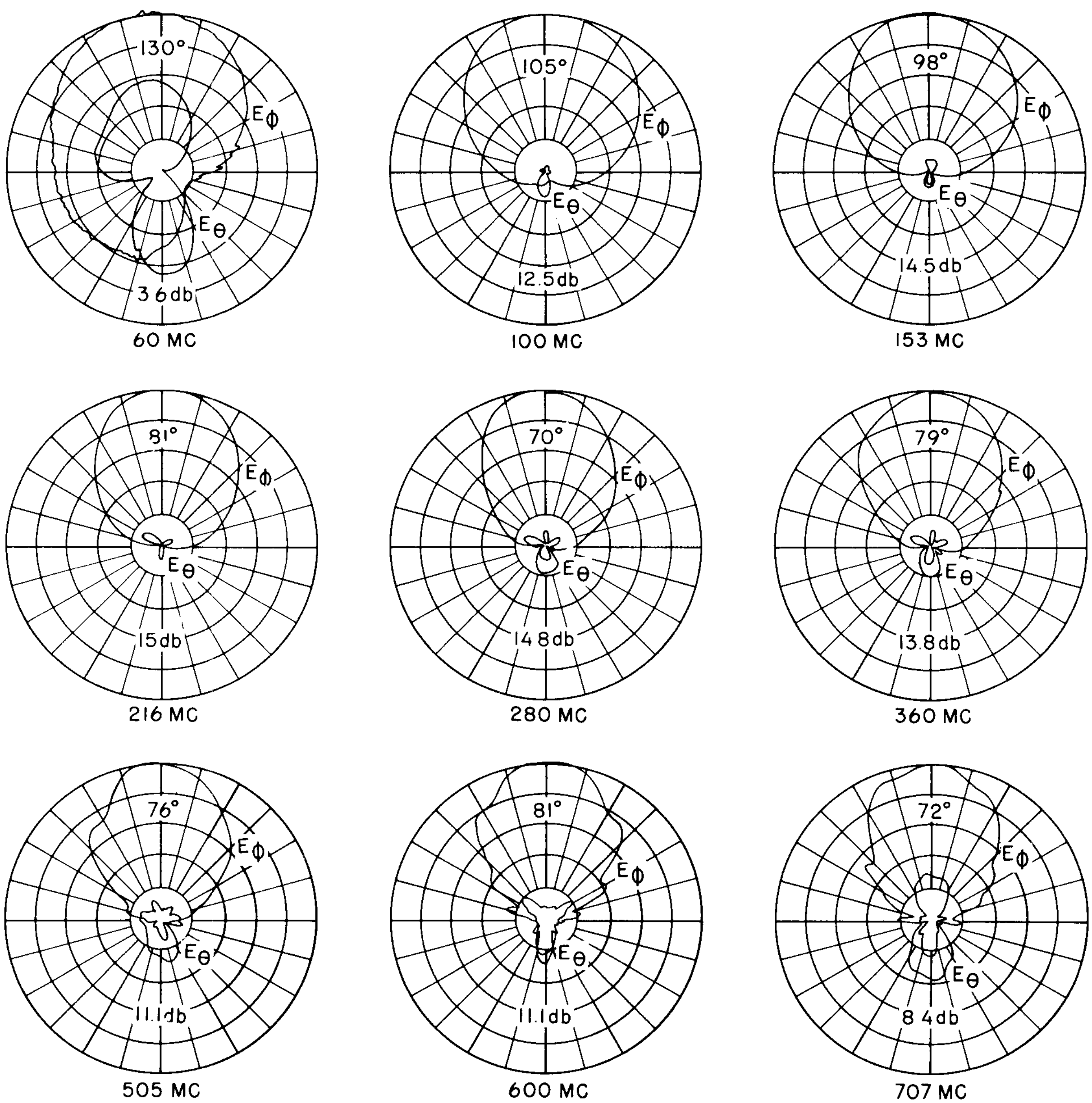


Figure 13. Vertical Polarization Relative Voltage Patterns Taken in Azimuthal Plane



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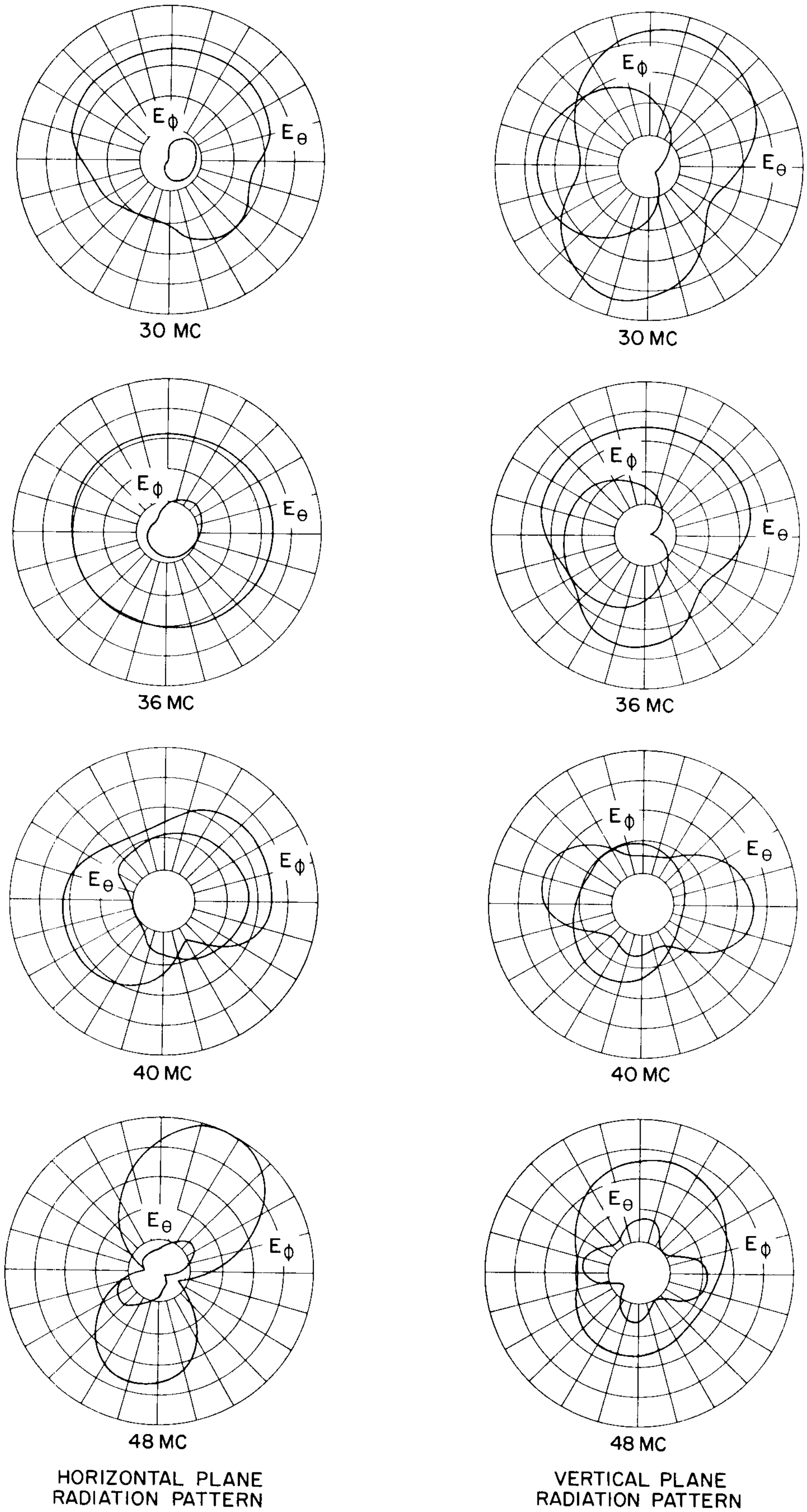


Figure 14. Radiation Patterns Below the Lower Cutoff Frequency



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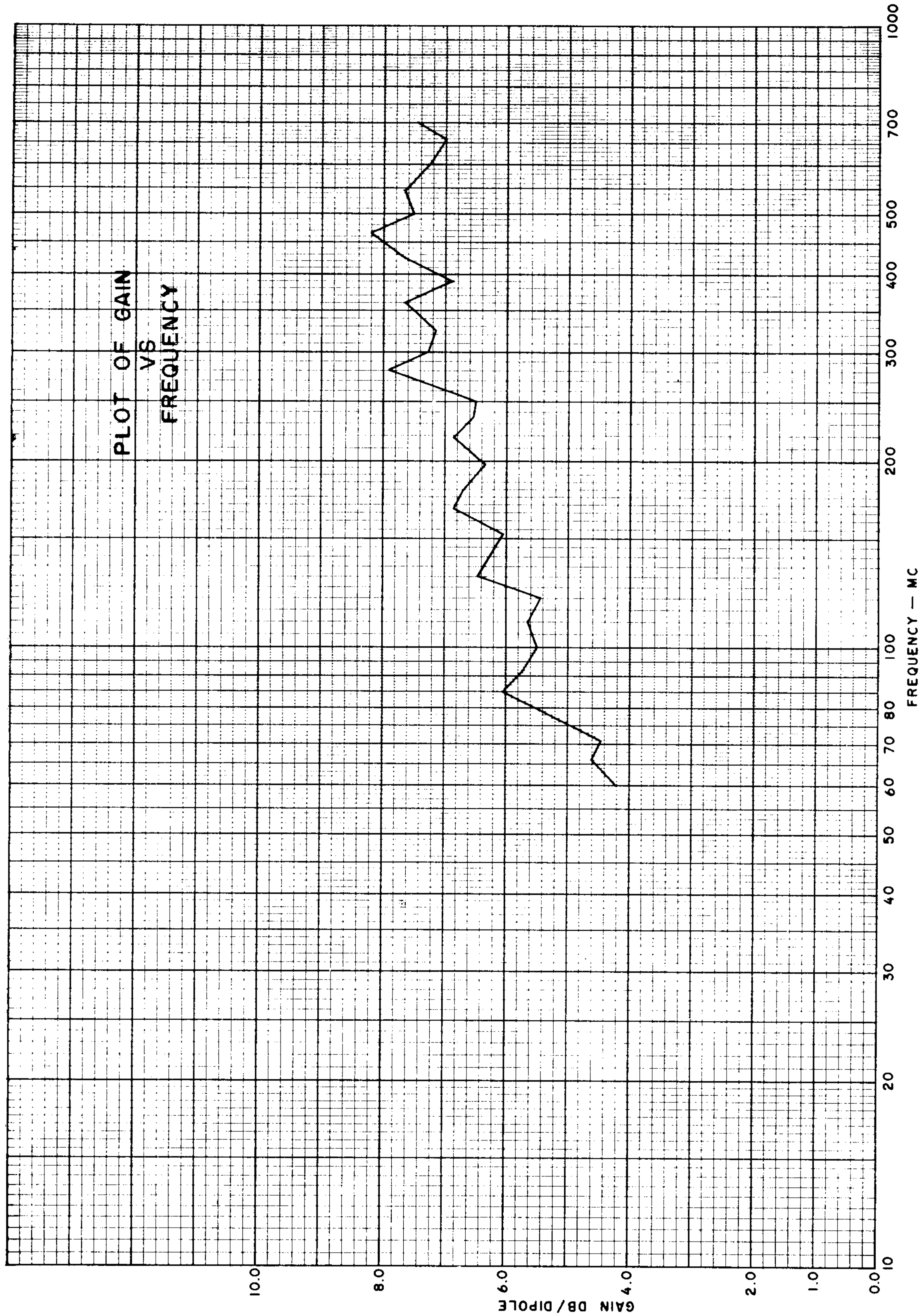


Figure 15. Plot of Gain Vs Frequency 

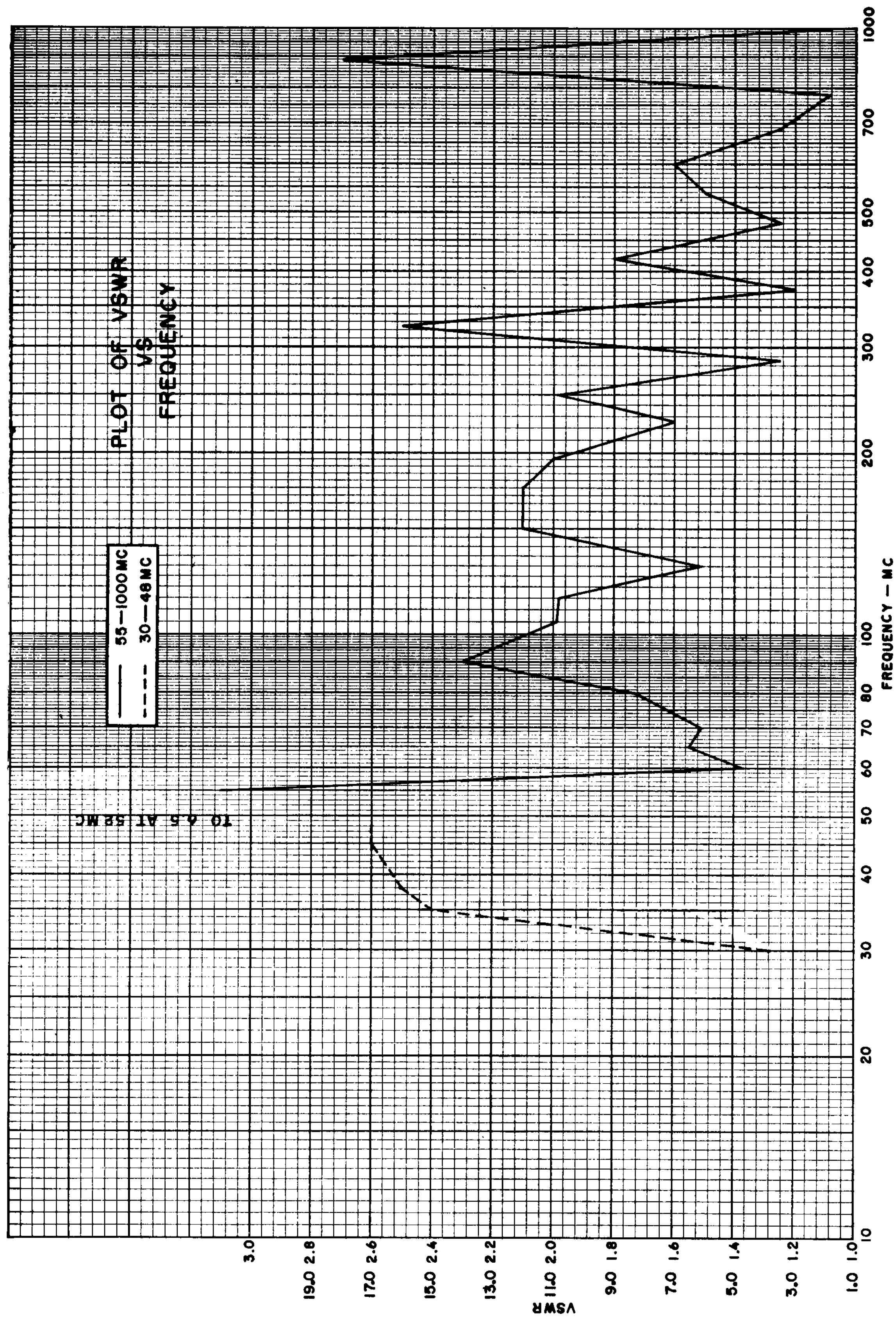


Figure 16. Plot of VSWR Vs Frequency



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